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AHC Media

Pediatric Sports-Related Injuries of the Lower Extremity: Ankle

Pediatric lower extremity injuries are common in the emergency department, especially with increasing sports specialization in young athletes. Acute care providers need to be familiar with common injury patterns, indications for radiographs, and more specialized imaging. Recognizing and maintaining a high degree of suspicion for high-morbidity injuries that may masquerade as an ankle sprain is critical. The authors review common injuries and also injuries that cannot be missed including Maisonneuve fracture, talar fractures, navicular fractures, Jones or pseudo-Jones fractures, Lisfranc injuries, and Salter-Harris fractures.

— Ann Dietrich, MD, FAAP, FACEP, Editor

Epidemiology

Millions of children between the ages of 6-18 years participate in organized sports each year.[1] Athletic participation yields many health and wellness benefits for children, but with increased sport specialization comes an increased risk of traumatic and overuse injuries.[2] Pediatric sports injuries are estimated to make up more than 2 million emergency department visits every year,[3] with an incidence rate of up to 35 per 100 children annually.[4] In the adolescent population, sports are the leading cause of injury, accounting for more than 30% of adolescent injuries worldwide.[5] Of these injuries, 60% or more involve the lower extremity,[5,6] and a high proportion of these involve the ankle. This article will emphasize how to perform a focused physical exam to empower emergency medicine physicians to accurately diagnose and manage commonly encountered and commonly missed foot and ankle injuries in the emergency department.

Pathophysiology

Pediatric patients are at higher risk for sports-related injuries because of immature skeletal growth.[2] Especially at risk is the physis, the cartilaginous growth plate of long bones that accounts for longitudinal growth. Injuries that cause benign strains and sprains in adults can result in serious growth plate injuries in children, as ligaments are structurally stronger than the physis until it is closed. Gradual closure of the physis occurs with puberty, and prior to closure, the physis is at particular risk for injury.[7-10] Because of overuse secondary to sport specialization, subacute stress fractures and apophysitis are becoming increasingly common indications for presentation to the emergency department. An apophysis is a location where muscle tendon inserts into a secondary ossification center. Pediatric athletes are particularly vulnerable to overuse injuries because their bones are weaker than those of adults and because they still have open growth plates.[10,11]

Ankle Sprains — General, Epidemiology, Etiology

Of the many lower extremity injuries sustained every year by pediatric athletes, a high proportion of these are ankle injuries. In the general population, ankle

EXECUTIVE SUMMARY

- The most common ankle injury seen in the emergency department and one of the most common sports-related injuries is a lateral ankle sprain, or inversion injury, accounting for more than 85% of all ankle sprains, with syndesmotic ankle sprains and medial sprains occurring much less frequently.
- Typically, patients with lateral ankle sprains present with pain, swelling, and inability to bear weight. On exam, patients have pain over the anterior talofibular and calcaneofibular ligaments; If pain is not present in these areas, the provider should be suspicious of a potentially more serious ankle injury.
- To aid in the diagnosis of a syndesmotic ankle injury, the provocative squeeze test can be performed, compressing the tibia and fibula together midway up the leg, with a positive test being pain at the distal tibiofibular joint.
- The Ottawa Ankle Rules are a reliable tool to exclude fractures in children older than 5 years of age who present to the emergency department with ankle and midfoot injuries. Imaging of the ankle is only necessary if there is pain in the malleolar zone plus one of the following: bony tenderness along the distal 6 cm of the posterior edge of the medial or lateral malleolus or inability to bear weight for four steps immediately after the injury and in the emergency department.
- For midfoot imaging, the rules recommend imaging only with pain in the midfoot region plus one of the following: bony tenderness at the navicular bone or the base of the fifth metatarsal or inability to bear weight for four steps immediately after the injury and in the emergency department
- Even if the patient's exam is consistent with an ankle sprain, and per clinical decision tools there is no indication for imaging, it is still important to push on six spots to guarantee to not miss a high-morbidity injury. These six spots are: 1) the proximal fibula to rule out Maisonneuve fracture; 2) talus to rule out a talar neck, dome, or lateral process fracture; 3) navicular bone to rule out navicular fracture; 4) base of the fifth metatarsal to rule out a Jones or pseudo-Jones fracture; 5) base of the first and second metatarsal to rule out a Lisfranc injury; 6) and the tibial and fibular physis to assess for Salter-Harris fracture.

sprains alone account for as many as 10% of emergency department visits[8] and as many as 15-20% of all sports injuries.[12] Serious ankle sprains are uncommon in the skeletally immature athlete.[13] This is because the ligaments of the ankle insert on the epiphyses distal to the physeal line, placing pediatric athletes at high risk for physeal fracture with injuries that would cause a sprain in adults. The physis often gives way when significant force is applied to the ankle, as it is the weakest link in the bone-tendon-bone interface.[10,13] Because some more serious injuries can mimic ankle sprains, it is important for emergency providers to recognize the normal pattern of injury in ankle sprains. This will allow the provider to identify when injury patterns deviate from the norm, thereby differentiating between a benign ankle sprain and more serious injuries that can mimic sprains. These injuries will be discussed later in the article.

Types of Sprains

The most common ankle injury seen in the emergency department and one of the most common sports-related injuries is a lateral ankle sprain, or inversion injury.[14] These account for more than 85% of all ankle sprains, with syndesmotic ankle sprains and medial sprains occurring much less frequently.[15] Lateral ankle sprains occur when the ankle is in a plantar flexed position and pathologically inverts and adducts, causing injury to the anterior talofibular (ATF) and calcaneofibular (CFL) ligaments,[12] which are shown in Figure 1.

Typically, patients with lateral ankle sprains present with pain, swelling, and inability to bear weight. On exam, patients have pain over the ATF (more anterior and superior than many providers realize) ligament and pain over the CFL ligament just distal to the distal fibula. If pain is not present in these areas, the provider should suspect a potentially more serious ankle injury.

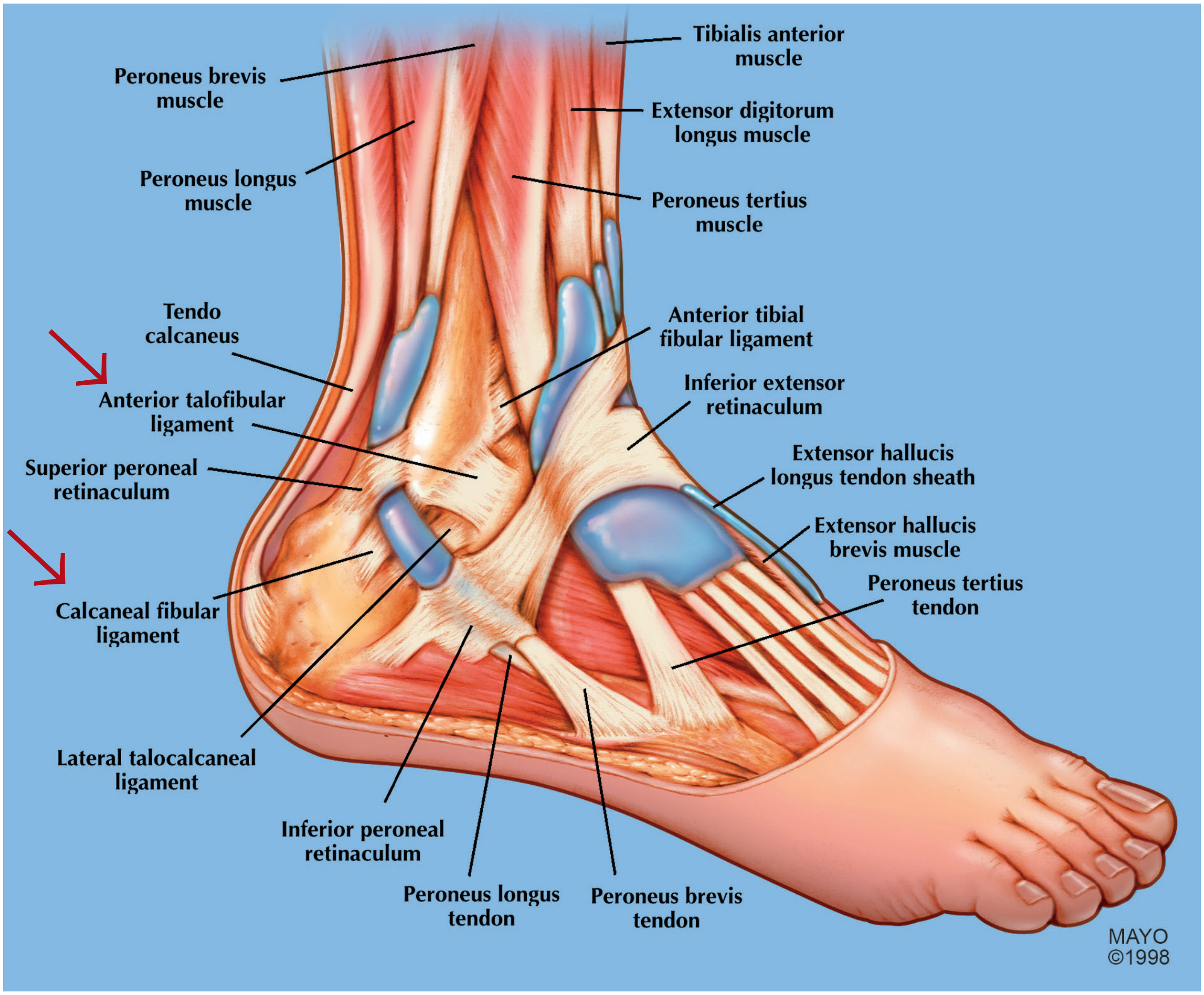
Medial ankle sprains, caused by an eversion injury when the foot is in a slight dorsiflexed position, are less common than lateral ankle sprains. This injury pattern results in injury to the deltoid ligaments on the medial aspect of the ankle. The deltoid ligaments are a primary stabilizer in the axial loaded ankle and have a superficial and deep component. On exam, patients have pain directly over the deltoid ligaments and medial ankle pain with passive eversion.

Syndesmotic ankle sprains, also known as high ankle sprains, may occur in the adolescent athlete and rarely in the pediatric athlete. These injuries are more common in collision sports such as football, wrestling, and hockey[16] and have been estimated to account for 11-17% of ankle sprains in athletes.[13,17] Syndesmotic sprains involve injury to the complex of connective tissues providing stability to the mortise of the ankle joint. Structures of this complex include the tibia, fibula, interosseous membrane, and four ligaments: the anterior inferior tibiofibular ligament, the posterior inferior tibiofibular ligament, the interosseous ligament, and the transverse tibiofibular ligament.[16] A significant force or load usually is required to cause a syndesmotic injury, and the most common mechanism is forceful external rotation of the foot and ankle. On exam, patients will exhibit point tenderness over the anterior or posterior inferior tibiofibular ligaments, which may extend up the leg if the interosseous membrane is involved. Tenderness also may be found over the deltoid or lateral ankle ligaments, as these structures often are injured simultaneously in a syndesmotic ankle injury. The provocative squeeze test can be performed to aid in diagnosis. The squeeze test is performed by compressing the tibia and fibula together midway up the leg causing shear strain to the distal syndesmosis ligaments. A positive test is pain at the distal tibiofibular joint.[18,19]

Grading of Ankle Sprains

Ankle ligament sprains classically are graded on a scale of I to III based on the degree of disability, swelling, and ligamentous injury (determined by the

Figure 1. Basic Ankle Anatomy



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amount of ligamentous laxity). Grade I is the mildest, and involves stretching of the ligaments without rupture or joint instability. Grade II is moderate in severity and involves a partial rupture of the ligament resulting in moderate pain and swelling as well as mild to moderate instability, resulting in difficulty with weight-bearing. Grade III injuries are the most severe and involve a complete ligament rupture, leading to significant pain, swelling, and hematoma formation. Grade III injuries cause severe functional impairment and instability.[12] Ligamentous stability can be assessed for the ATF through the anterior drawer test, and compared to the unaffected side, and CFL integrity can be assessed through a talar tilt test.[19] Because most patients in the emergency department are in too much acute pain for these exams to be performed adequately, the utility of grading ankle sprains in the emergency department is limited. Ultimately, if the patient has significant swelling and loss of function (ability to bear weight), this represents a higher ankle sprain that may require more aggressive immobilization with appropriate physical therapy and primary care follow-up.

Diagnosis of Ankle Sprains

The first step in diagnosis of ankle sprains is classification of which type of ankle sprain occurred based on clinical history and a focused physical exam of the ligaments discussed above. To confidently diagnose an ankle injury as a sprain rather than a more significant injury, the pain and swelling documented on exam must coincide with the injury pattern expected. Despite only identifying fractures in up to 20% of patients,[20] X-rays are obtained in 60-100% of children with ankle injuries.[21] Clinical decision tools can aid in identifying injuries that require imaging while minimizing unnecessary studies. (*See Table 1.*) The Ottawa Ankle Rules were developed by Stiell et al as a clinical decision tool to help determine when radiologic

Table 1. Clinical Decision Tools for Imaging Ankle Injuries

Ottawa Ankle Rules	Low Risk Ankle Rule
Validated for pediatric patients (Dowling et al.) Only image if: • Pain in the malleolar zone PLUS • Bony tenderness along the distal 6 cm of the posterior edge of the medial or lateral malleolus OR • Inability to bear weight for four steps both immediately and in the emergency department	Developed for pediatric patients No imaging if all criteria are met: • Acute injury (< 3 days old) • Not at risk for pathologic fracture • No congenital anomaly of feet/ ankles • Can express pain/tenderness • Pain/swelling limited to distal fibula or lateral ligaments distal to the anterior tibial joint line • No gross deformity, neurovascular compromise, or distracting injury
Source: Author adapted.	

evaluation is necessary in acute ankle and midfoot injuries.[22] They have been found to be 100% sensitive in the adult population for ruling out fractures; by using this tool, emergency departments have been able to decrease X-ray use, wait times, and cost.[23] A meta-analysis by Dowling et al found the Ottawa Ankle Rules to be a reliable tool to exclude fractures in children older than 5 years of age who present to the emergency department with ankle and midfoot injuries.[24] The Ottawa Ankle Rules state that imaging of the ankle is only necessary if there is pain in the malleolar zone plus one of the following: bony tenderness along the distal 6 cm of the posterior edge of the medial or lateral malleolus or inability to bear weight for four steps immediately after the injury and in the emergency department. In terms of midfoot imaging, the rules recommend imaging only with pain in the midfoot region plus one of the following: bony tenderness at the navicular bone or the base of the fifth metatarsal or inability to bear weight for four steps immediately after the injury and in the emergency department. Navicular and fifth metatarsal injuries will be discussed later in this article. Based on the data by Dowling et al, application of the Ottawa Ankle Rules in pediatric patients would reduce X-ray usage by about 25%.[24]

The Low Risk Ankle Rule is a tool that was developed specifically for children to help determine when X-rays are needed. Pediatric patients are considered low risk if the injury is acute (defined as less than 3 days old), if they are not at risk for pathologic fracture (for example, children with a focal bone lesion or osteogenesis imperfecta), if they do not have a congenital anomaly of the feet or ankles, if they are able to express pain or tenderness, if pain and swelling are limited to the distal fibular or surrounding lateral ligaments distal to the anterior tibial joint line, and if no gross deformity, neurovascular compromise, or other distracting injury is present.[25] In the Low Risk Ankle Rule, distal fibular avulsion fractures and nondisplaced Salter-Harris I and II fractures are considered low-risk injuries since they are managed with supportive splinting, crutches if needed, and return to activities as tolerated.

The Low Risk Ankle Rule has been shown to have a sensitivity of 98-100% for clinically important ankle fractures as well as to reduce the number of X-rays and, thus, cost in the emergency department.[26,27]

Even if the patient's exam is consistent with an ankle sprain, and per clinical decision tools there is no indication for imaging, it is still important to push on six spots to guarantee not to miss a high-morbidity injury. These six spots are: 1) the proximal fibula to rule out Maisonneuve fracture; 2) talus to rule out a talar neck, dome, or lateral process fracture; 3) navicular bone to rule out navicular fracture; 4) base of the fifth metatarsal to rule out a Jones or pseudo-Jones fracture; 5) base of the first and second metatarsal to rule out a Lisfranc injury; 6) and the tibial and fibular physes to assess for Salter-Harris fracture. The mechanics and management of these injuries will be discussed later in the article. To avoid missing high-morbidity injuries in the ankle, a simple ankle sprain can be diagnosed only if three criteria are met: 1) there is no pain over these six locations, 2) the exam is consistent with ligamentous injury, and 3) there is no indication for imaging per Ottawa Ankle Rules.

Management of Ankle Sprains

Although management of ankle sprains depends on the type of sprain as well as the severity, the overall goals of management for ankle sprains in the emergency department are to control pain, reduce post-injury edema, and functionally support the ankle to allow early mobilization. Minor ankle sprains caused from inversion strain can be managed conservatively with rest, ice, elevation, and immobilization.[13] Options include bracing, Aircast, Ace bandage, and a walker boot. Recent studies suggest bracing, Aircast, and Ace bandage allow more rapid return to function by allowing early mobilization. The overall consensus is that if a patient has a mild or moderate ankle sprain, an Ace bandage[28] or Aircast should be used.[29] If an Aircast is provided, an Ace bandage also should be used to prevent dependent anterior edema that can limit plantar and dorsiflexion. If the patient has considerable swelling, loss of function, and instability, a walker boot will immobilize the injury more aggressively and will allow functional return to activities of daily living. With the exception of syndesmotic ankle sprains, numerous studies show that early weightbearing and mobilization more rapidly improve functional return after an ankle sprain.[28,29,30] Syndesmotic ankle sprains are more severe and require more aggressive management with a walker boot and crutches.[14] The prolonged course of this injury, as well as the importance of following up with a specialist, should be discussed with the patient.

All ankle sprain patients should be advised of the importance of physical therapy in follow-up. Therapy that emphasizes ankle strength and proprioception can be effective for the prevention of ankle sprains in athletes with previous sprains.[12,32] Inappropriate follow-up can lead to chronic ankle instability, impingement, and early osteoarthritis.

Table 2. Six Foot/Ankle Injuries Not to Miss in the Emergency Department

Injury	Exam	Management
Maisonneuve fractures	Pain over the proximal fibula	Long-leg posterior splint Urgent orthopedic follow-up
Talar fractures	Pain over the talar dome/neck/lateral process	Non-weightbearing in walker boot or posterior splint Specialist follow-up in one week
Navicular fractures	Pain over the dorsal or medial navicular	Non-weightbearing in walker boot Specialist follow-up in one week
Fifth metatarsal fractures	Pain over the fifth metatarsal	Pseudo-Jones: Ortho shoe or walker boot Jones: Non-weightbearing in posterior splint Specialist follow-up in one week
Lisfranc injuries	Pain/bruising/swelling over the midfoot	Non-weightbearing in posterior splint Specialist follow-up in one week
Salter-Harris fractures	Pain over the tibial/fibial growth plate	Salter-Harris I & II: Non-weightbearing in posterior splint Specialist follow-up in one week Salter-Harris III & IV: Long-leg splint, urgent orthopedic follow-up

What if It's Not an Ankle Sprain? Injuries Not to Miss in the ED

For emergency medicine physicians, ankle sprains are ultimately a diagnosis of exclusion. The emergency provider first must consider injuries that can mimic ankle sprains but are associated with a high morbidity. (*See Table 2.*) These include Maisonneuve fracture, talar fractures, navicular fractures, Jones or pseudo Jones fractures, Lisfranc injuries, and Salter-Harris fractures.

Can't-miss Injury #1: Maisonneuve Fractures

Proximal fibular fractures, or Maisonneuve fractures, are caused by external rotation of the ankle joint with force transmitted through the tibiofibular syndesmosis. Although proximal fibula fractures alone do not require surgical intervention, they do suggest an injury from a high degree of force and may be associated with a medial malleolus fracture or a rupture of the deltoid ligament, anterior talofibular ligament, or interosseous ligament.[33] Injuries to these ligaments may be difficult to appreciate on exam, but are associated with a high degree of ankle mortise instability that may require surgical intervention.[34] The presence of proximal fibular pain necessitates X-rays of the tibia/fibula and an ankle X-ray, including a gravity view. The gravity view will help ascertain if there is considerable mortise instability that will require operative intervention. Maisonneuve fractures should be placed in a long-leg posterior splint with urgent orthopedic follow-up.

Can't-miss Injury #2: Talar Fractures

Although less common than other ankle injuries, fractures to the talus (*see Figure 2*) can occur with rotational injuries to the ankle and have a high rate of complications. If the talar neck, dome, or lateral process is painful to palpation on exam, the provider should obtain ankle X-rays, including an oblique view. Talar neck fractures are the most common talar fracture but are often overlooked in the setting of ankle injuries.[35] These fractures are caused by extremes of dorsiflexion. On exam, patients will have focal tenderness over the talar neck associated with edema and pain with range of motion. Talar neck fractures are best viewed on the lateral view of the ankle X-ray. The blood supply to the talus is distal and there is a retrograde supply to the talar body from branches of the posterior tibial artery. This leads to a risk of osteonecrosis if the talar neck is disrupted.[36] Avascular necrosis of the talar body is a devastating consequence of talar neck fractures, making talar fractures high risk if not managed appropriately.[37,38] Talar neck fractures (*see Figure 3*) also can lead to post-traumatic arthritis of the subtalar joint.[36] These fractures require close follow-up by an orthopedist.

Talar dome fractures (*see Figure 4*), or osteochondral dome fractures, occur with impaction in inversion and eversion ankle injuries. This results in trauma to the cartilage of the talus and its underlying subchondral bone.[39] The most common location for these injuries is anterolateral or posteromedial. Radiographically, talar dome fractures are best visualized on the mortise view. However, up to 30% of talar dome compression fractures are not seen on radiography, and patients with these fractures are often mistakenly diagnosed with an ankle sprain.[40] Clinically, patients present with point tenderness and pain with range of motion. Missed injuries can lead to non-union and early-onset arthritis; thus, specialist follow-up is imperative..

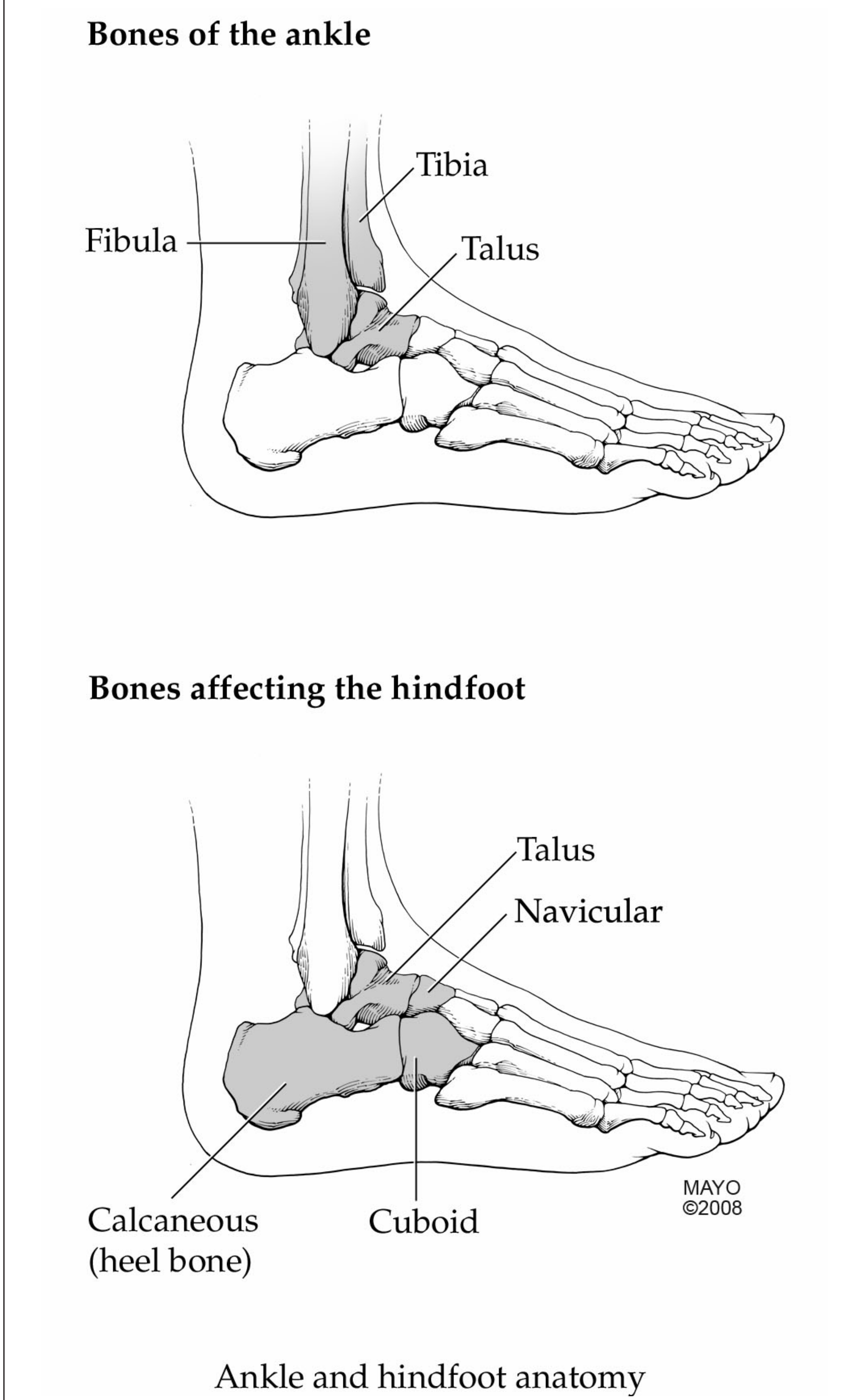
Fractures to the lateral process of the talus, or snowboarder's fractures, are uncommon, but their incidence is increasing because of the growing popularity of snowboarding.[41] These fractures are thought to occur as a result of pathologic dorsiflexion and inversion, and they happen with greater frequency in snowboarders because of the impact of landing from a jump while their foot is held in dorsiflexion inside their boot.[42]

These are exceptionally difficult to diagnose, as they present identically to an inversion ankle sprain with pain in the location of the ATF ligament. The lateral talus is the insertion point of the ATF. On exam, pain is most prominent 1 cm distal to the lateral malleolus. Pain with dorsiflexion and external rotation should raise concern since this maneuver causes impingement on the fracture site but does not stress the ATF ligament and, thus, inversion ankle sprains should not hurt with this maneuver. These fractures have a miss rate of up to 60%, and missed injuries can lead to non-union, chronic ankle pain, and early-onset arthritis. They are best seen on mortise and oblique views. If a provider has clinical suspicion for a talar fracture (even if X-rays are negative), the patient should be placed in a walker boot or posterior splint with a non-weightbearing status and have follow-up imaging and reassessment by an orthopedic specialist in one week. CT scan is recommended in patients who present with a history of a snowboard injury or jump plus one or more positive Ottawa ankle criteria.[41]

Can't-miss Injury #3: Navicular Fractures

The navicular bone (*see Figure 2*) is critical for maintaining the medial longitudinal arch; thus, delayed diagnoses can lead to chronic gait disturbances and disabling foot pain. Navicular fractures are classified as dorsal or tuberosity avulsion fractures or body fractures. Avulsion fractures are the most common fractures and are associated with a low-energy mechanism of injury, while body fractures require high-energy mechanisms like a motor vehicle collision.[43] Dorsal avulsion fractures (*see Figure 5*) result from a disruption of the talonavicular ligament associated with inversion ankle injuries. Tuberosity avulsion fractures occur with forced eversion of the ankle and midfoot, causing traction to the posterior tibial tendon or deltoid ligament, which then results in the avulsion fracture. Tuberosity fractures (*see Figure 6*) must be differentiated from an accessory navicular on X-ray. An accessory navicular is usually bilateral and appears as a smooth corticated bone medial to the navicular, while a tuberosity fracture has an irregular trabecular appearance.[44] These injuries are difficult to appreciate on initial routine X-rays and may be visible only in about half of cases;[13] thus, they require a high index of suspicion. Dorsal avulsion fractures are best seen on lateral view, and tuberosity avulsion fractures on AP and external oblique views. Because of the high morbidity associated with these fractures, the emergency provider should palpate the medial navicular and N spot for every rotational ankle and foot injury. The medial navicular is the

Figure 2. Bones of the Ankle



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bony prominence just distal to the talus at the mid-arch of the foot. The N spot is the dorsal navicular between the anterior tibial tendon and the extensor hallucis longus tendon. Pain in these locations requires non-weightbearing and placement in either a walker boot or posterior splint, as well as specialist follow-up in one week.[45]

Can't-miss Injury #4: Jones and Pseudo-Jones Fractures

Fifth metatarsal fractures are the most common metatarsal fractures in children and comprise about 5% of all fractures in children.[46] These fractures occur with inversion ankle injuries or rotational foot injuries. Figure 7 depicts basic bony anatomy of the foot. Pain with palpation to the fifth metatarsal necessitates dedicated foot films to examine the zone-specific location of the injury. There are three zones of injury in which fifth metatarsal fractures can occur. Zone 1 injuries, also called pseudo-Jones fractures, occur during an inversion injury to the ankle when the peroneal brevis tendon or lateral band of the plantar fascia causes an avulsion injury to the base of the fifth metatarsal. These injuries can be appreciated on the lateral view of the

Figure 3. Talar Neck Fracture

Figure 4. Talar Dome Fracture

ankle, but require a dedicated foot X-ray to determine displacement. Patients with pseudo-Jones fractures may bear weight as tolerated in a post-op shoe or walker boot and follow up with a specialist in one week. It is important to note that a fifth metatarsal apophysis can be mistaken as a zone 1 injury.[47] An apophysis is an ossification center to which a tendon or ligament attaches. The fifth metatarsal apophysis is a vertically oriented bony fragment that runs parallel to the metatarsal shaft. Avulsion fractures are oriented transversely. It is important to recognize differences on X-ray, as a fifth metatarsal apophysis can be painful and swollen in the setting of fifth metatarsal apophysitis,[13] also known as Iselin disease. Figure 8 shows both a fifth metatarsal avulsion fracture and a fifth metatarsal apophysis.

Zone 2 injuries are also referred to as Jones fractures. These occur with an adducted force applied to a plantar flexed foot[48] and happen more commonly in the adolescent athlete than in younger patients.[13] Jones fractures involve a fracture to the proximal metaphyseal diaphyseal junction. There is a limited vascular supply to this area, leading to a high risk of delayed healing and non-union with these injuries.[49] Patients should be strictly non-weightbearing and placed in a posterior splint in the emergency department. They can be transitioned to a short leg cast in the outpatient setting. Zone 3 injuries can occur with blunt trauma, rotational injuries, or repetitive stress from athletic activities. These are proximal diaphyseal fractures located distal to the fourth and fifth metatarsal articulation. Management is the same as zone 2 injuries, with strict non-weightbearing and placement in a posterior splint with transition to a short leg cast.[50] Zone I and II injuries should be followed up by an orthopedic specialist in one week.

Can't-miss Injury #5: Lisfranc Injuries

Lisfranc injuries are complex and often missed injuries that are characterized by a ligamentous injury or fracture and/or dislocation to the tarsometatarsal joint. The Lisfranc joint is critical to stability of the midfoot, and mismanaged injuries can lead to debilitating foot pain and gait disturbances.[51] These injuries are caused by plantar flexion with a rotational force identical to the mechanism of an inversion sprain. They occur more frequently in football players[52] or children jumping from a height, hence their nickname of "bunk bed fractures."[53] On physical exam, plantar bruising is classic. Ligamentous injury may be subtle with only midfoot pain noted. Fracture dislocations are characterized by swelling and inability to bear weight.[2] The patient will have pain with pronation and abduction of the foot.

In patients with a suspected Lisfranc injury, it is critical to obtain weightbearing images (AP, lateral, oblique) of the foot. Radiographic signs of Lisfranc injury on AP film include a separation greater than 2 mm between the base of the first and second metatarsals (*see Figure 9a*); "fleck sign," which is a fracture at the base of the second metatarsal;[54] and disrupted alignments of the lateral border of the first metatarsal with the lateral border of the medial cuneiform as well as the medial border of the second metatarsal with medial border of the middle cuneiform.[55] As X-ray signs are subtle, a film of the contralateral foot is helpful for comparison (*see Figure 9b*). CT or MRI in the outpatient setting may be helpful if a Lisfranc injury is suspected but not seen on plain films.[5] It is important for the emergency physician to have a high index of suspicion for these injuries, and if X-rays are negative but there is still clinical concern, the patient should be non-weightbearing and placed in a posterior splint or walker boot with close outpatient follow-up and referral to orthopedics.

Figure 5. Dorsal Navicular Avulsion

Can't-miss Injury #6: Salter-Harris Fractures

In pediatric patients with open growth plates, the physician should palpate a sixth location: the tibial and fibular growth plate. It is critical not to be fooled into thinking that lateral ankle pain with normal X-rays in the pediatric patient is diagnostic of an ankle sprain. Pain over the tibial or fibular growth plate represents a Salter-Harris type I fracture and must be managed appropriately with placement in a posterior splint and non-weightbearing.[30] Salter-Harris fractures will be discussed in more detail in the next section.

Ankle Fractures — General, Epidemiology

Ankle fractures make up about 5% of pediatric fractures and 15% of growth plate injuries. They occur more often in boys than girls and peak between

Figure 6. Navicular Tuberosity Fracture

the ages of 8 and 15 years.[55,56,57] These injuries occur more often in overweight athletes[58] and in basketball, soccer, and football players.[59] As mentioned previously, pediatric patients are less prone to ligamentous injuries because ligaments tend to be stronger than open growth plates. As a result, minimal trauma that generally would cause a sprain in an adult (for example, an inversion injury) may cause physeal fractures in pediatric patients.[32] However, it is also important to ensure that physical exam findings correlate with radiographic findings because accessory ossification centers seen on X-ray sometimes are misinterpreted as fractures.[55]

Distal Tibial Fractures

General

The distal tibial physis is responsible for 45% of overall growth of the tibia, and growth usually continues until 14 years of age in girls and 16 years of age in boys.[56] Before the physis closes completely, there is an 18-month transitional period during which up to 15% of physeal fractures in adolescents occur.[57] Fractures of the distal tibial physis are the second most common physeal fracture, second only to fractures of the distal radius.[55] Fractures of the distal tibia are classified into Salter-Harris types I-IV.[60]

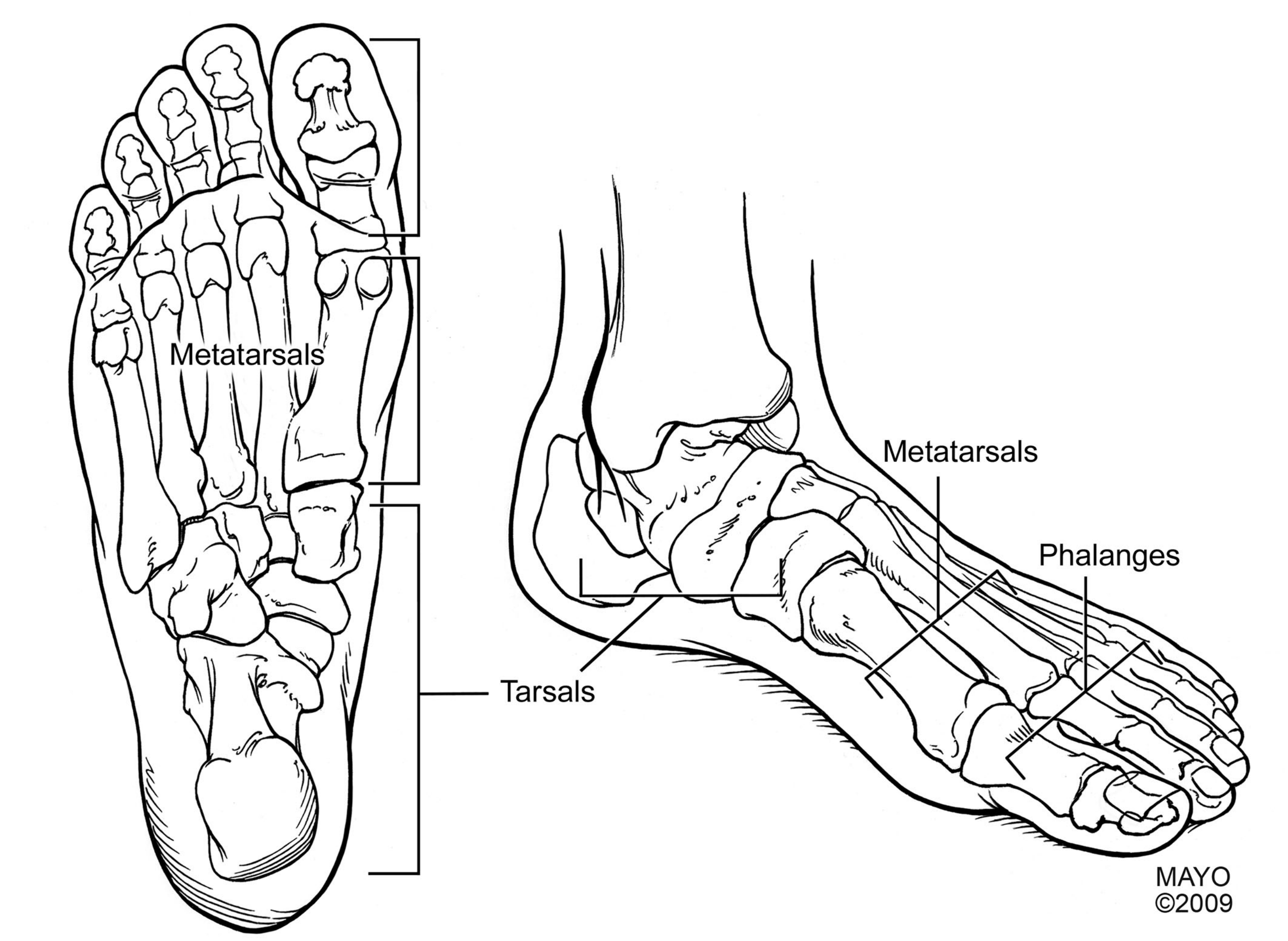
Salter-Harris Types I and II

Salter-Harris type I and II fractures have a lower risk of growth plate arrest, or premature physeal closure, than types III and IV and are managed similarly in the emergency department.[56,61] A Salter-Harris type I fracture is a transverse fracture through the physis. It is important to note that these fractures can lead to widening of the physes but may not show any initial X-ray abnormalities. Thus, the emergency physician needs to have a high index of suspicion for these fractures when there is pain over the medial malleolus or tibial growth plate, even in the setting of negative X-rays. Salter-Harris type II fractures are the most common type, accounting for about 40% of distal tibial fractures.[56,57] These fractures are through the physis, with extension of the fracture pattern through the metaphysis. Salter-Harris types I and II fractures can result in growth plate arrest in patients.[62] In the emergency department, Salter-Harris types I and II fractures should be placed in a posterior splint with the patient non-weightbearing. The splint can be transitioned to a cast in one week when the patient follows up with orthopedics.[13]

Salter-Harris Types III and IV

Salter-Harris type III fractures extend through the physis and downward through the epiphysis and account for about 25% of distal tibial fractures.[63] Near the epiphysis is the reserve zone

Figure 7. Basic Bony Anatomy of the Foot



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of the physis that contains progenitor cells for continued physeal growth; thus, appropriate reduction of these fractures is critical, as inappropriate reduction can lead to physeal arrest.[11,57] Salter-Harris type III fractures also represent intra-articular fractures, so anatomic reduction is critical to prevent intra-articular step off. CT scan may be helpful to determine the degree of displacement. Tillaux fractures are a Salter-Harris type III variant that occurs in adolescents during the 18-month transitional period when the tibial physis is closing medially to laterally, leaving the lateral physis susceptible to fracture and displacement.[64] Tillaux fractures occur when an external rotation force is applied to the partially closed tibial growth plate.[13] This results in an avulsion injury at the insertion of the anterior inferior tibiofibular ligament on the lateral distal tibial epiphysis.[64] Tillaux fractures account for 3-5% of overall pediatric ankle fractures.[56] Salter-Harris III fractures often require reduction. The technique is plantar flexion, internal rotation, and manual pressure over the displaced fragment. No more than two attempts at reduction should be made.[56,57] Patients should be non-weightbearing and placed in a long leg splint with the foot in internal rotation. These injuries require urgent orthopedic follow-up.

Salter-Harris type IV fractures are the most severe and carry the highest risk of growth arrest.[56] These fractures extend through the physis, metaphysis, and epiphysis, creating an unstable growth plate fracture fragment that also has an intra-articular component. Salter-Harris type IV fractures include trimalleolar fractures, defined as fracture lines in three anatomic planes (*see Figure 10*), and lateral triplane fractures. Lateral triplane fractures comprise 5-15% of pediatric ankle fractures[56] and, like Tillaux fractures, they occur during the transitional period of physeal closure.[57] In lateral triplane fractures, the metaphysis fracture line extends in the coronal plane, the epiphysis fracture in the sagittal plane, and the physeal fracture in the axial plane. This creates an unstable fracture fragment in the medial epimetaphysis of the tibial shaft.[65] Triplane fractures typically occur with external rotation to a supinated foot. Anatomic reduction is critical and usually requires specialist consultation. Closed reduction is performed via axial traction and internal rotation. As with Salter-Harris III fractures, CT scan is

Figure 8. Fifth Metatarsal Fracture and Fifth Metatarsal Apophysis

This X-ray from a 12-year-old male shows both a fifth metatarsal fracture and a fifth metatarsal apophysis. There is a transverse lucency extending through the base of the right fifth metatarsal consistent with a nondisplaced fracture. The fracture line extends almost to the tarsal metatarsal joint but does not extend intra-articularly. This injury was sustained while playing football.

helpful to determine the degree of displacement, and these patients should be placed in a long-leg splint with internal rotation.[66] These patients require urgent orthopedic follow-up and management. Open reduction is recommended for physeal fractures with a gap of 3 mm or more.[13,58,67]

Distal Fibula Fractures

Salter-Harris Fractures

The fibula is a non-weightbearing bone, so more aggressive weightbearing can be tolerated by patients with fractures to the fibula. Salter-Harris type I and II fractures comprise about 90% of distal fibula fractures.[58] Salter-Harris type I fractures of the fibula are common and often are missed or misdiagnosed as a sprain. The classic history is an external rotation force. It is important for the emergency provider to palpate over the fibular physis, about 2 cm from the distal fibula, and not to assume that lateral ankle pain is secondary to sprain. Localized pain and swelling over the distal fibular physis is diagnostic. X-rays are usually normal in these fractures, making it a clinical diagnosis. Patients should be placed in a walker boot, weightbearing as tolerated, and primary care follow-up for repeat exam in one week. Salter-Harris type II fractures are not commonly recognized in the fibula and management is the same as for Salter-Harris type I fractures. Fractures of the distal fibula combined with a Salter-Harris type II injury of the distal tibia are a common ankle injury in pediatric patients.[13] Isolated Salter-Harris type III and IV fractures of the fibula are rare and need to be distinguished from an accessory ossification center, os fibulare.[58]

Os fibulare is an accessory ossicle distal to the fibula that can be misinterpreted as a fracture.[68] It is thought to be secondary to an old avulsion fracture or non-union of an accessory ossification center. The os fibulare may become symptomatic with overuse, and especially is seen in ballet dancers and gymnasts.[69] Avulsion of the accessory ossification center also can occur and is based on clinical suspicion and pain with palpation.[70] These avulsion fractures can be considered Salter-Harris II fractures.[71] If painful with palpation on exam, the patient should be placed in a walker boot, weight-bearing as tolerated, with primary care follow-up.

Conclusion

Pediatric lower extremity injuries commonly present in the emergency department, especially with increasing sports specialization in young athletes. Injuries to the ankle and foot make up the majority of these injuries, and ankle sprains are a frequent occurrence. X-rays are not always necessary, as both the Ottawa Ankle Rules and the Low Risk Ankle Rule demonstrate. However, the emergency physician must be sure not to miss a high-morbidity injury that may masquerade as an ankle sprain. Thus, it is important to rule out Maisonneuve fracture, talar fractures, navicular fractures, Jones or pseudo-Jones fractures, Lisfranc injuries, and Salter-Harris fractures by a careful exam and obtain appropriate radiographic images. Pediatric patients are more vulnerable to ankle fractures than adult patients because children have open growth plates. Likewise, ankle fractures in the pediatric population have particular implications because of physeal anatomy. A comprehensive understanding of both common and high-morbidity pediatric ankle and foot injuries, as well as how to assess and

Figure 9. Lisfranc Injuries

Figure 9a represents a Lisfranc injury. This occurred after an inversion injury of the ankle and was missed on the patient's initial emergency department visit.

Figure 9b shows weight-bearing images obtained on the same patient one month later, when she re-presented with ongoing midfoot pain and inability to bear weight. The stress view as well as visualization of the contralateral foot allows the lateral subluxation at the second tarso-metarsal joint of the left foot to be identified.

treat them, is crucial for the emergency physician.

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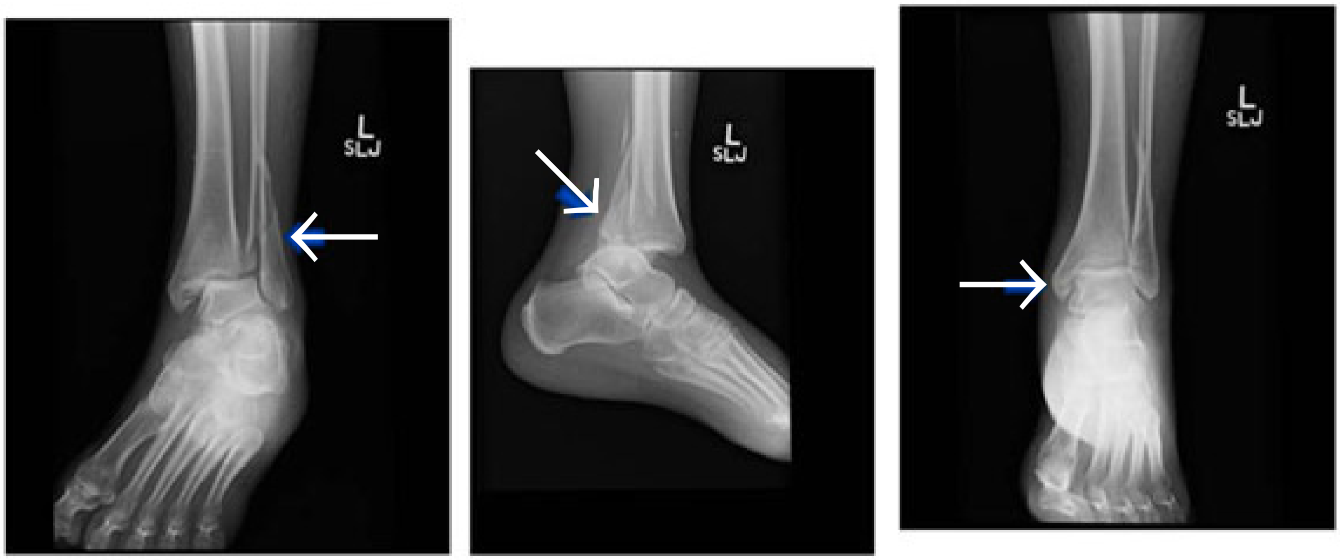
Figure 10. Salter-Harris IV Trimalleolar Fracture



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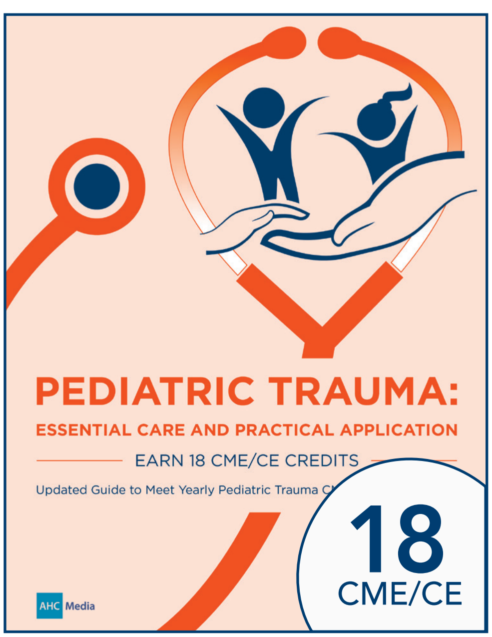

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1. In an inversion ankle sprain, which of the following ligaments is most commonly injured?
   a. Anterior talofibular ligament
   b. Deltoid ligament
   c. Interosseous ligament
   d. Posterior talofibular ligament
2. Which of the following is ***not*** a component of the Ottawa Ankle Rules?
   a. Bony tenderness at the distal or posterior edge of the lateral malleolus
   b. Bony tenderness at the distal or posterior edge of the medial malleolus
   c. Pain over the proximal fibula
   d. Inability to bear weight for four steps in the emergency department
3. A snowboarder presents with lateral ankle pain. Which of the following is the most likely underlying fracture?
   a. Talar neck fracture
   b. Lateral talar process fracture
   c. Distal fibula fracture
   d. Navicular fracture
4. The best management for a grade II ankle sprain is which of the following?
   a. Posterior leg splint with weightbearing as tolerated status
   b. Posterior leg splint with non-weightbearing status
   c. Aircast with weightbearing as tolerated status
   d. Aircast with non-weightbearing status
5. A patient presents with ankle pain and pain dorsal mid-foot between the anterior tibial tendon and the extensor hallucis longus tendon. What is the best management for this injury?
   a. Posterior leg splint with weightbearing as tolerated status
   b. Posterior leg splint with non-weightbearing status
   c. Aircast with weightbearing as tolerated status
   d. Aircast with non-weightbearing status
6. A vertically oriented bony fragment is seen at the base of the fifth metatarsal. This represents which of the following?
   a. Jones fracture
   b. Pseudo-Jones fracture
   c. Os navicularis
   d. Fifth metatarsal apophysis
7. A fracture to the proximal metaphyseal diaphyseal junction of the fifth metatarsal is appreciated on X-ray. What is the best management?
   a. Walker boot, weightbearing as tolerated status
   b. Walker boot, non-weightbearing status
   c. Post-op shoe, weightbearing as tolerated status
   d. Aircast, weightbearing as tolerated status
8. A patient presents with pain at the dorsal base of the first and second metatarsal. What other X-ray view needs to be obtained?
   a. Gravity stress view
   b. Harris view
   c. Weightbearing view
   d. Zanca view
9. A Salter-Harris type III fracture that results from an avulsion injury at the insertion of the anterior inferior tibiofibular ligament on the lateral distal tibial epiphysis is characteristic of which of the following fractures?
   a. Tillaux fracture
   b. Triplane fracture
   c. Maisonneuve fracture
   d. Monteggia fracture
10. A patient presents one week after an eversion ankle injury with pain midway between the anterior tibial tendon and extensor hallucis tendon. Which of the following is the correct injury and management for this patient?
    a. Navicular fracture: walker boot and non-weightbearing
    b. Navicular fracture: walker boot, weightbearing as tolerated
    c. Navicular tuberosity fracture: walker boot, non-weightbearing
    d. Navicular tuberosity fracture: walker boot, weightbearing as tolerated

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PEDIATRIC EMERGENCY MEDICINE REPORTS

Practical, Evidence-Based Reviews in Pediatric Emergency Care

Pediatric Sports-related Injuries of the Lower Extremity: Ankle

Six Foot/Ankle Injuries Not to Miss in the Emergency Department

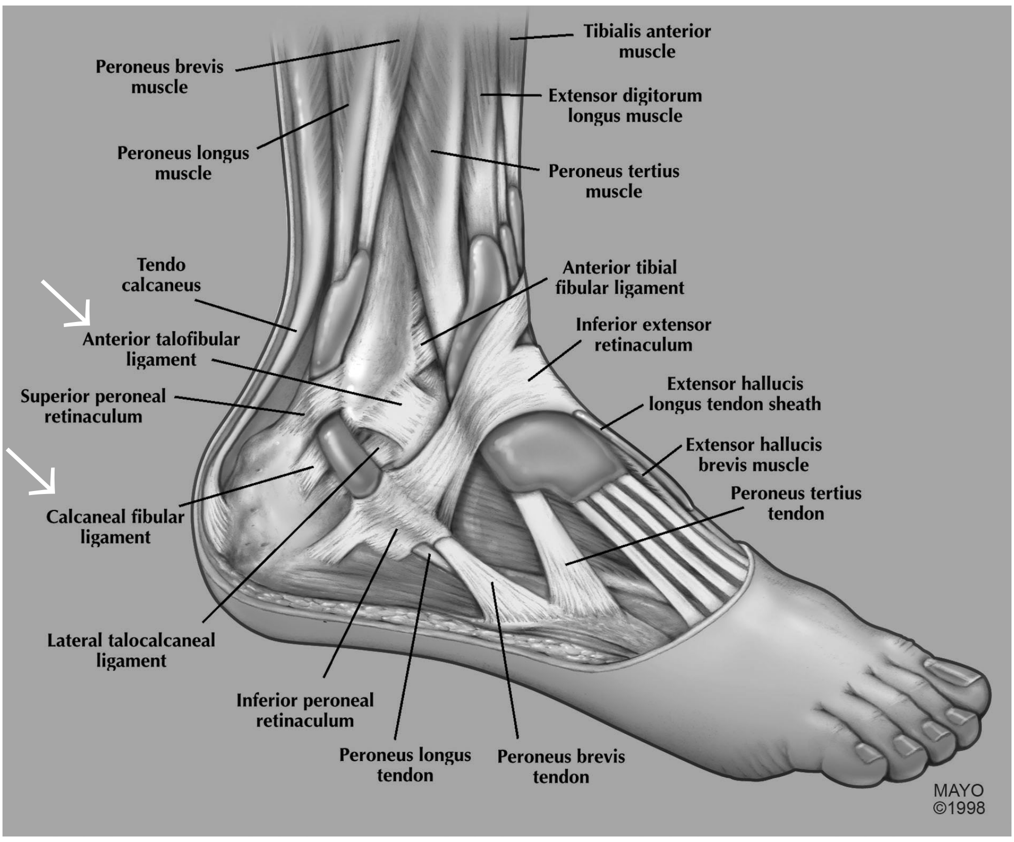
Injury	Exam	Management
Maisonneuve fracture	Pain over the proximal fibula	Long leg posterior splint Urgent orthopedic follow-up
Talar fractures	Pain over the talar dome/neck/lateral process	Non-weightbearing in walker boot or posterior splint Specialist follow-up in one week
Navicular fracture	Pain over the dorsal or medial navicular	Non-weightbearing in walker boot Specialist follow-up in one week
Fifth metatarsal fracture	Pain over the fifth metatarsal	Pseudo-Jones: Ortho shoe or walker boot Jones: Non-weightbearing in posterior splint Specialist follow-up in one week
Lisfranc injuries	Pain/bruising/swelling over the midfoot	Non-weightbearing in posterior splint Specialist follow-up in one week
Salter-Harris fractures	Pain over the tibial/fibial growth plate	Salter-Harris I & II: Non-weightbearing in posterior splint Specialist follow-up in one week Salter-Harris III & IV: Long-leg splint, urgent orthopedic follow-up

Clinical Decision Tools for Imaging Ankle Injuries

Ottawa Ankle Rules	Low Risk Ankle Rule
Validated for pediatric patients (Dowling et al.) Only image if: • Pain in the malleolar zone PLUS • Bony tenderness along the distal 6 cm of the posterior edge of the medial or lateral malleolus OR • Inability to bear weight for four steps both immediately and in the emergency department	Developed for pediatric patients No imaging if all criteria are met: • Acute injury (< 3 days old) • Not at risk for pathologic fracture • No congenital anomaly of feet/ankles • Can express pain/tenderness • Pain/swelling limited to distal fibula or lateral ligaments distal to the anterior tibial joint line • No gross deformity, neurovascular compromise, or distracting injury

Source: Author adapted.

Basic Ankle Anatomy



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Salter-Harris IV Trimalleolar Fracture

Talar Dome Fracture

Talar Neck Fracture

Supplement to *Pediatric Emergency Medicine Reports*, October 2016: "Pediatric Sports-related Injuries of the Lower Extremity: Ankle." Authors: Kristina Colbenson, MD, Board-certified Emergency Medicine and Sports Physician, Mayo Clinic, Rochester, MN; and Erika Hoenke McMahon, MD, Resident Physician, Mayo Clinic, Rochester, MN.

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